Ph6820 Homework 5. Due on April 28.

1. Approximate the Gamow Peak .

(from Shu's The Physical Universe)

Imagine two nuclei with charges Z_1 and Z_2 colliding. Show that if the particles are traveling at relative velocity v (where $v = v_1 - v_2$), the distance of closest approach (before the particle is repelled by the Coloumb barrier) is given by:

$$r = \frac{2Z_1 Z_2 e^2}{mv^2} \tag{1}$$

As we discussed in class, this semester and last, the probability that the particle will tunnel through the Coulomb barrier is:

$$P \propto exp^{-4\pi^2 Z_1 Z_2 e^2/hv} \tag{2}$$

For a gas in thermodynamic equilibrium, the probability of having a velocity v is given by the Maxwellian:

$$P \propto exp^{-mv^2/2kT} \tag{3}$$

Multiply the two probabilities to get the probability of a thermonuclear reaction. Show that the maximum probability happens for a velocity of:

$$v = (4\pi^2 Z_1 Z_2 e^2 kT/hm)^{1/3} \tag{4}$$

For the first reaction of the PPI chain at a $T = 1.5 \times 10^7 K$, calculate the closest approach r for this value of v.

Next show that the maximum probability will be

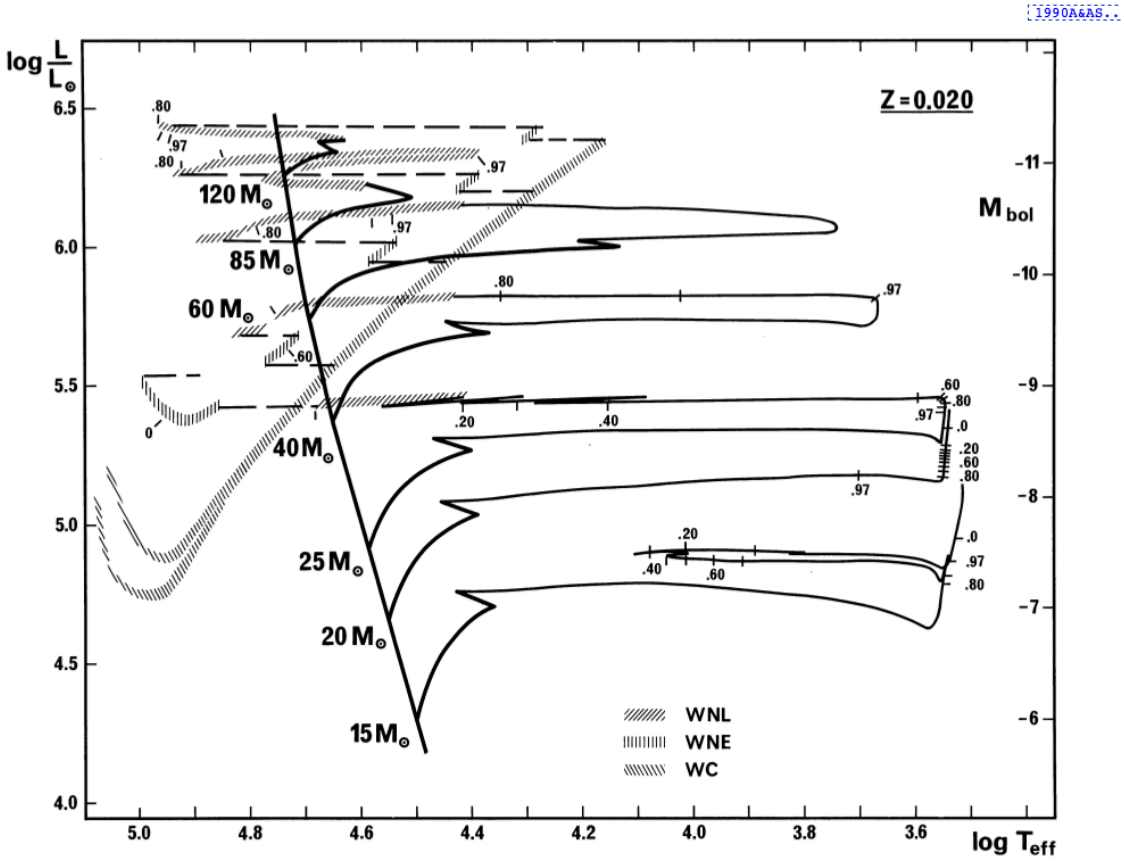
$$P_{max} \propto e^{-3/2(4\pi^2 Z_1 Z_2 e^2/h)^{2/3}(m/kT)^{1/3}} \tag{5}$$

Finally, defining $T_0 = (3/2)^3(4\pi^2 Z_1 Z_2 e^2/h)^2(m/k)$, plot the resulting probability

$$P_{max} \propto e^{-(T_0/T)^{1/3}} \tag{6}$$

What does this probability say about the temperature sensitivity of the reaction?

2. Determine the Eddington luminosity for each mass and draw it over the tracks. Using the "classical" Eddington luminosity which uses the Thompson scattering cross section. How does the maximum luminosity of the tracks compare to the Eddington luminosity?



Maeder et al. 1990 A&AS 84, 139